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EXECUTIVE SUMMARY

This report, entitled "**Hazard Analysis of Commercial Space Transportation**," is devoted to the review and discussion of generic hazards associated with the ground, launch, orbital and re-entry phases of space operations. Since the DOT Office of Commercial Space Transportation (OCST) has been charged with protecting the public health and safety by the Commercial Space Act of 1984 (P.L. 98-575), it must promulgate and enforce appropriate safety criteria and regulatory requirements for licensing the emerging commercial space launch industry. This report was sponsored by OCST to identify and assess prospective safety hazards associated with commercial launch activities, the involved equipment, facilities, personnel, public property, people and environment. The report presents, organizes and evaluates the technical information available in the public domain, pertaining to the nature, severity and control of prospective hazards and public risk exposure levels arising from commercial space launch activities. The US Government space-operational experience and risk control practices established at its National Ranges serve as the basis for this review and analysis.

The report consists of three self-contained, but complementary, volumes focusing on Space Transportation: I. Operations; II. Hazards; and III. Risk Analysis. This Executive Summary is attached to all 3 volumes, with the text describing that volume highlighted.

Volume I: Space Transportation Operations provides the technical background and terminology, as well as the issues and regulatory context, for understanding commercial space launch activities and the associated hazards. Chapter 1, The Context for a Hazard Analysis of Commercial Space Activities, discusses the purpose, scope and organization of the report in light of current national space policy and the DOT/OCST regulatory mission. It also introduces some basic definitions and outlines the approach to a generic Hazard Analysis for future commercial space operations. Chapter 2, Range Operations, Controls and Safety, discusses the tracking and flight control systems, as well as the mission planning and approval process. The chapter describes the prelaunch ground safety and launch flight safety procedures developed and enforced at the National Ranges to ensure launch and mission success, personnel safety and to protect the public from the potential impacts of a launch accident. Chapter 3, Expendable Launch Vehicles (ELV) Characteristics, introduces the basic propulsion technology, configuration and capability for operational US launch vehicles (Titan, Delta, Atlas/Centaur, Scout) likely to be commercialized in the near term. ELV historical launch performance, operational reliability data and

the bearing this record has on public safety issues are also discussed. Chapter 4, Launch and Orbital Operations, describes the phases of space operations, from ground preparation to launch, through orbital transfer, operation and re- entry. It also provides the reader with sufficient background to understand possible ELV and mission failures during launch, orbital maneuvers and orbit insertion and operation.

Volume II : Space Transportation Hazards identifies and discusses the major and generic classes of hazards associated with each phase of space operations. Chapter 5, Pre-launch and Launch Hazards, identifies the types of hazards, such as explosions, fires, toxic vapors and debris, as a function of accident scenario and time after launch and defines their nature and severity indices. Further, a comparative perspective on potential ELV space launch accidents is provided by analogy to more common and socially accepted transportation and industrial accidents involving chemicals and fuels. Chapter 6 is devoted to Orbital Collision Hazards, shedding light on the Low Earth Orbit (LEO) and Geosynchronous Earth Orbit (GEO) space environment and the increasing threat of on orbit collisions to spacecraft. The sources and density of orbital debris are discussed and their implications for the probabilities of collisions involving operational satellites are quantified. Chapter 7 defines and reviews Re-Entry Hazards and their quantification by addressing the orbital lifetime and decay of space objects depending on their orbital characteristics, the behavior and survivability of space objects upon re-entering Earth's atmosphere and the uncertainties associated with predicting points of entry and ground impacts.

Volume III: Space Transportation Risk Analysis introduces the methods and uses of Risk Analysis as they apply to the qualitative evaluation and quantitative assessment of public risk exposure from commercial space operations. Chapter 8 introduces the concepts of risk acceptability and relative risk and the tools of Risk Analysis Methodology developed for a broad range of industrial and regulatory purposes. These include: failure analysis methods (which focus on failure modes and failure chains); consequence analysis methods (which focus on the severity of possible consequences of failures); hazard analysis methods (focused on the identification and ranking of hazards); and integrated probabilistic risk analysis methods, such as Fault Tree Analysis, which quantify risk as the mathematical product of an event probability and its consequence magnitude. Chapter 9 discusses the Applications of Risk Analysis to Space Launch Operations as used to date by the Government Agencies (NASA, DOD, DOE) concerned with assuring and maintaining high operability and safety standards for space launch operations. The chapter reviews the objectives, concepts, tools and uses of risk analyses

conducted at the National Ranges by sponsoring agencies, in light of de-facto risk/safety goals, criteria and priorities. Finally, Chapter 10 provides an integrated Generic Risk Assessment of Representative Launch Scenarios background by reviewing the risk associated with typical ELV missions from current Range locations. Then the benefits of established Range Safety Controls are quantified, relative to their hypothetical absence, employing the framework of a simplified Community Damage (COMDAM) model in a typical Risk Matrix evaluation procedure.